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Metacognitive scaffolding during collaborative learning: a promising combination

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Abstract This article explores the effect of computerized scaffolding with different scaffolds (structuring vs. problematizing) on intra-group metacognitive interaction. In this study, we investigate 4 types of intra-group social metacognitive activities; namely ignored, accepted, shared and co-constructed metacognitive activities in 18 triads (6 control groups; no scaffolds and 12 experimental groups; 6 structuring scaffolds and 6 problematizing scaffolds). We found that groups receiving scaffolding showed significantly more intra-group interactions in which the group members co-construct social metacognitive activities. Groups receiving problematizing scaffolds showed significantly less ignored and more co-constructed social metacognitive interaction compared to groups receiving structuring scaffolds. These findings indicate that scaffolding positively influenced the group members' intra-group social metacognitive interaction. We also found a significant relation between students' participation in intra-group social metacognitive interaction and students' metacognitive knowledge. Twelve percent of the variance in students' metacognitive knowledge was explained by their participation in intra-group shared social metacognitive interaction. Therefore, future research should consider how to design scaffolds that elicit intra-group social metacognitive interaction among group members to enhance the development of students' metacognitive knowledge.

Keywords Shared regulated learning · Social metacognition · Scaffolding · Collaborative learning · Elementary education

Introduction

Recently the term social has been placed at the heart of regulated learning (Hadwin et al. 2011). As such, self-regulated learning can become socially regulated learning when a

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learner's regulatory activities are supported or constrained by others (co-regulation) or when individuals negotiate shared task perceptions, goals and strategies (socially shared regulation) (Hadwin et al. 2011; Iiskala et al. 2011; Molenaar and Järvelä 2014; Molenaar et al. 2010; Volet et al. 2009). Moreover, Hadwin and Jarvela (2013) recently made a compelling argument that groups often require support to improve socially regulated learning. This paper builds on this argument, investigating how scaffolding can support groups to produce socially regulated learning. The notion behind this study is that scaffolding in a group setting has a different potential for learning than scaffolding in an individual setting due to its possible effects on the interaction among group members.

Regulation of learning in groups entails the discussion of social metacognitive activities that control and monitor the group's learning (Iiskala et al. 2011; Molenaar et al. 2010). Research has indicated that high quality discussions among group members positively influence the group's regulation of learning (Goos et al. 2002; Iiskala et al. 2011; Lin and Sullivan 2008). This is in line with collaborative learning research that indicates that the effectiveness of students' collaborating during learning depends on the quality of the interaction among the group members (Webb 2009). Learning is enhanced when students discuss each other's contributions by providing feedback, participating in discussion, giving critical comments and co-constructing arguments (Teasley 1997; Weinberger and Fischer 2006). This interaction among the group members provides opportunities for sharing and building upon each other's knowledge (Van Boxtel 2004).

Unfortunately, like individuals, groups also often do not sufficiently control and monitor their learning (Molenaar et al. 2011). Scaffolding can be used to foster socially regulated learning (Azevedo and Cromley 2004; Schoor and Bannert 2012). However, until now, little has been known about how scaffolding enhances socially regulated learning and affects group members' intra-group social metacognitive interaction. Research has shown that intra-group interaction can be supported by instructional design, such as scripts, jigsaws and role play (Dillenbourg 1999; Rummel and Spada 2005). But these designs have not been used to support socially regulated learning and intra-group social metacognitive interaction (Hadwin and Jarvella 2013). Therefore, the first research question addressed in this article is: What are the effects of metacognitive scaffolds on intra-group social metacognitive interaction during collaborative learning? We will examine this question by comparing students in a control group with students in two experimental groups receiving computerized scaffolds. Students in the experimental groups are supported with two different forms of metacognitive scaffolds (problematizing or structuring scaffolds). To further build our understanding of the potential of intra-group social metacognitive interaction, we will also examine the impact of the nature and quality of the interaction on students' metacognitive knowledge. Because most of the research so far has focused on dissecting how intra-group social metacognitive interaction occurs, little is known about the effect of these interactions on student's learning. Therefore, the second question we formulated is: How is a student's participation in intra-group social metacognitive interaction related to a student's metacognitive knowledge?

This study examines how metacognitive scaffolding and, in particular, different forms of scaffolds effect students' interaction related to metacognitive activities in groups and hence fosters their metacognitive knowledge. Building on two research traditions, we first discuss theories of socially regulated learning and social metacognitive activities and the relation between group interaction and students' metacognitive knowledge. Second, we discuss how metacognitive scaffolding and different forms of scaffold foster students' regulation of learning while collaborating in groups.

Socially regulated learning and social metacognitive activities

In small groups, socially regulated learning is important for the group to foster the learning of individual group members. Socially regulated learning entails the selection and use of appropriate cognitive and motivational strategies to attain learning goals and the application of social metacognitive activities to control and monitor the group's learning (Hadwin and Oshige 2011; Iiskala et al. 2011; Volet et al. 2009). As such, these social metacognitive activities are an essential element of the group's socially regulated learning. For example, group members familiarize themselves with the learning assignment (orientate), plan the group's activities, monitor the group's actions and evaluate the accuracy of the group's learning and finally reflect on the learning strategies followed by the group. Besides regulating the group's learning, learners in groups also need to control and monitor their own and fellow group members' learning (Hadwin and Oshige 2011). In order to understand how metacognitive activities support the regulation of learning in groups, different forms of metacognitive activities are distinguished at various points along the social spectrum, namely individual, other and social metacognitive activities (Liskala et al. 2004; Iiskala et al. 2011; Hadwin and Oshige 2011).

Individual metacognitive activities occur when a student controls or monitors his/her own cognitive activities (Volet et al. 2009). For example, a student evaluates whether the answer he calculated for the group assignment is correct. This form of regulated learning has a close relation to our traditional view of metacognitive activities. Metacognition was originally defined as "cognition over cognition" or "knowledge about knowing", which a learner needs to control and monitor his learning (Flavell 1979). In order to distinguish clearly between cognitive and metacognitive activities, Nelson (1996) defined the object- and meta-level of learning. Cognitive activities are those activities dealing with the content of the task (the object-level) and metacognitive activities are those activities dealing with controlling and monitoring cognitive activities (the meta-level), such as orientation, planning, monitoring, evaluation and reflection (Meijer et al. 2006). Other and social metacognitive activities are unique for collaborative learning settings. *Other* metacognitive activities refer to transitional activities between two group members, when one student controls or monitors another student's cognitive activity (Iiskala et al. 2011; Volet et al. 2009). For example, a group member evaluates the answer another group member produced, supporting the evaluation of this group member's cognitive activities. *Social* metacognitive activities occur when one or more group members control or monitor the group's collaborative cognitive activities (Volet et al. 2009). For example, the group members discuss whether the answer produced by the group is correct supporting the evaluation of the groups' cognitive activities. Social metacognition is an intergral part of interactions between group members and previous research has shown that there are different ways students discuss and share metacognitive activities (Iiskalla et al. 2011; Molenaar et al. 2011). In this study we focus on the intra-group social metacognitive interaction and the different types of social metacognitive interaction that occur in group discussions.

Intra-group social metacognitive interaction and learning

Collaborative learning research has a long tradition of studying the interaction between students (Teasley 1997; Weinberger and Fischer 2006). In small groups, learning activities are formed through reciprocal activities between the students, in which they interact in different ways (Volet et al. 2009). Consequently, students influence each other in a spiral-like fashion; for example when a student contributes a social metacognitive activity to the social system, this can elicit new cognitive or social metacognitive activities from the other group members (Salomon 1993). This micro-level interaction among students defines the quality of the students' interaction. Different views of collaborative learning distinguish a number of types of interaction among students, such as shared or co-constructed interaction related to cognitive activities (Damon 1984; Rafal 1996; Van Boxtel 2004).

During intra-group cognitive interaction, information flows between peers (Hatano 1993). In this type of interaction group members share existing knowledge and acknowledge each other's contributions, mostly without disagreement or demands for justification (Mercer 1996; Webb 2009). On the other hand, during co-constructed intra-group cognitive interaction, students built on each other's' activities explaining and questioning each other's thinking and providing feedback (Van Boxtel 2004). Characteristic of this type of interaction is that students formulate actions and knowledge that individual group members would not be able to generate themselves (Damon 1984; Rafal 1996). Moreover, it is widely acknowledged that not all collaboration is effective; students are known to ignore each other's contributions and to concentrate on their own thinking (Chi 2009).

Following this distinction made in research on collaborative learning, in this study we also distinguish different types of intra-group social metacognitive interaction, namely ignored, shared and co-constructed social metacognitive activities. When focusing on the intra-group social metacognitive interaction, it is important to distinguish the level at which the discussion occurs. When an interaction is followed by a metacognitive remark this leads to an exchange of metacognitive activities. In contrast, when the conversation is continued with a cognitive remark, this can indicate an active response to the metacognitive remark. Therefore, we add a fourth type, namely accepted metacognitive activities. Figure 1 shows the four types of intra-group social metacognitive interaction. On the left side of the picture students are not responding with a metacognitive reply. On the right side students engage in discussions of social metacognitive activities.

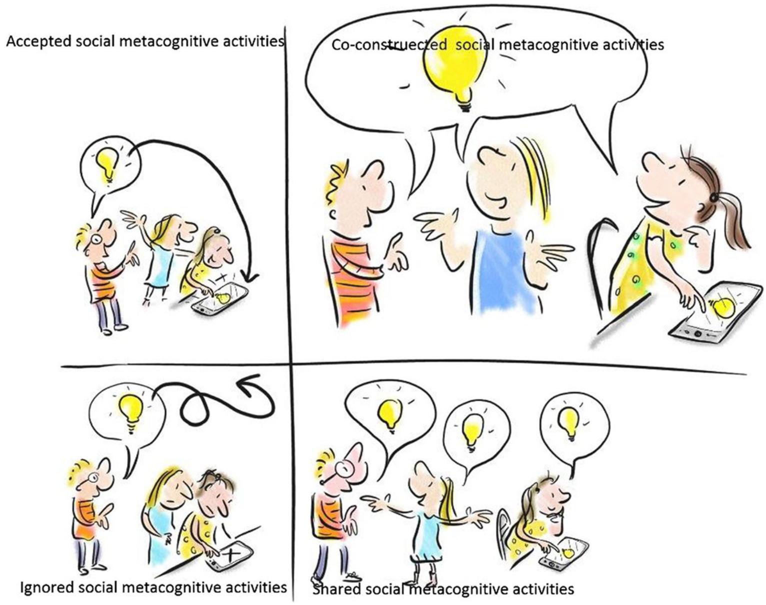


Fig. 1 Four types of intra-group social metacognitive interaction: ignored, accepted, shared and co-constructed social metacognitive activities

In the bottom left panel of Fig. 1 an ignored social metacognitive activity is depicted. This happens when a group member attempts to control or monitor the group's learning activities, but the other group members ignore this effort. For example, a student evaluates the answer the group produced, commenting that the answer is wrong. The other group members do not respond to his comment. In the top left panel an accepted social metacognitive activity is represented. This occurs when group members show their agreement with a metacognitive remark by implementing it in a cognitive activity. For example, a student evaluates the answer the group produced, commenting that the answer is wrong. Another group member starts to reassess the answer. This indicates that the evaluation activity is noticed and followed up in the reassessment, thus the group members engage with this metacognitive remark with a cognitive contribution.

On the right side of Fig. 1 two types of interaction are depicted in which groups engage in discussions about social metacognitive activities, i.e. shared and co-constructed social metacognitive activities. In the bottom right panel of Fig. 1 a shared social metacognitive activity is depicted. Shared interaction occurs when students share their metacognitive ideas: they respond to each other's contributions, but they do not build on each other's ideas towards a new idea. For example, a student evaluates the answer the group produced, commenting that the answer is wrong. Another group member comments that he believes the answer might be wrong too.

Exchanging metacognitive comments can also result in new ideas, when students do advance each other's metacognitive remarks. This is referred to as co-constructed social metacognitive activities, an example of which is depicted in the upper right panel of Fig. 1. In instances of this type of interaction, group members build on each other's ideas, collaboratively constructing a metacognitive activity to regulate their collaborative learning. For example, a student evaluates the answer the group produced commenting that the answer is wrong. Another group member comments that he believes the answer might be right and justifies this comment. The third student continues to evaluate the comments of the other two.

Distinguishing these types of intra-group social metacognitive interaction, we previously found that co-constructed social metacognitive activities are rare, which is in line with earlier findings from collaborative learning research (Van Boxtel 2004; Molenaar et al. 2014). In addition, collaborative learning research consequently found that cognitive activities in high quality interactions foster students' learning (Teasley 1997; Roschelle 1996; Stahl et al. 2006; Suthers et al. 2010). Interaction supports group members to learn from each other through exchanging, sharing and co-constructing knowledge (Chi 2009; Doise 1990; Doise and Mugny 1984; Hatano 1993; Mercer 1996; Piaget 1932; Van Boxtel 2004; Webb 2009). Consequently, intra-group social metacognitive interaction may increase students' metacognitive knowledge. Ignored metacognitive activities, when noticed, exemplify unsuccessful social metacognitive activities. Accepted metacognitive activities highlight successful metacognitive activities and shared metacognitive activities support the exchange of existing metacognitive knowledge among the group members. Finally, co-constructed metacognitive activities support the collaborative creation of new metacognitive knowledge. Although we did find the four types of intra-group social metacognitive interaction in a previous study, less is known about how and to what extent students' intra-group social metacognitive interaction supports the exchange of metacognitive knowledge among the group members, which consequently can be beneficial for individual group members' metacognitive knowledge. In this study, we therefore focus on the relation between different types of intra-group social metacognitive interaction activities and students' metacognitive knowledge. By doing this, we aim to increase knowledge of the role of intra-group social metacognitive interaction in student learning.

Effects of scaffolding on intra-group social metacognitive interaction

Although high quality interaction can foster student's learning, it happens relatively infrequently (Weinberger and Fischer 2006). In addition, research suggests that collaborating students have difficulties to sufficiently control and monitor their learning (Hadwin and Oshige 2011). Metacogntive scaffolds can trigger and support small groups to perform social metacognitive activities (Molenaar et al. 2011; Azevedo et al. 2008; Schoor and Bannert 2012). Scaffolding is defined as providing assistance to a group of students on an as-needed basis, decreasing (fading) the assistance as the competence of the group increases (Wood et al. 1976). Research indicates that scaffolding facilitates learning because it supports learners in activities they are unable to accomplish successfully by themselves and develops knowledge and skills needed to perform future tasks (Hmelo-Silver and Azevedo 2006; Pea 2004; Sharma and Hannafin 2007). The essential elements in the scaffolding process are diagnosis, calibration and fading (Puntambekar and Hubscher 2005). The abilities of the group must be diagnosed continuously in order to define appropriate scaffolds. This diagnosis supports careful selection, or calibration, of the appropriate scaffolds to support the group's progress and a successive reduction of support, fading, when the group has mastered all aspects of the task (Molenaar et al. 2011). Scaffolding that conforms to these elements follows the three characteristics of scaffolding put forward by Van der Pol and colleagues (2010), namely contingency (scaffolds are calibrated according to the diagnoses), fading (reduction of scaffolding when diagnoses indicate that students succeed for themselves) and transfer of responsibility from the scaffolder to the scaffoldee (Van der Pol et al. 2010).

In this study, metacognitive scaffolding is provided by an intelligent tutoring system (Molenaar and Roda 2008; Molenaar et al. 2013). Metacognitive scaffolds of different types (orientation, planning and monitoring scaffolds) are provided at points during learning when regulation is expected to be useful for learning following the preparation, execution and reflection phase, as defined in self-regulated learning theory (Zimmerman 2002; Winne and Hadwin 2010) and augmented with metacognition theory (Veenman et al. 2005; Molenaar et al. 2013). For example, when the group commences a new task a planning scaffold is provided. The group's progress is diagnosed based on their behavior over time in the computerized learning environment. Based on the group's progress, calibration is made; the right moment for providing the right type of scaffold is determined. For example, at the beginning of a new task or previously unsuccessfully ended task, a planning scaffold is provided. All groups receive scaffolds the first time they start a new task; fading is implemented by only providing scaffolds only when group progress is hampered. Therefore, responsibility for social regulation and the execution of metacognitive activities is progressively transferred back to the group.

As part of the process of scaffolding described above, two different mechanisms can be used to explain how students learn from scaffolding (Reiser 2004). Structuring simplifies the learning assignment by reducing its complexity, clarifying the underlying components and supporting performance (e.g. providing the students with an example of a plan for the assignment). Problematizing increases the complexity of the learning assignment by emphasizing certain aspects of the assignment and asking learners to clarify the underlying components and perform actions to construct their own strategies (e.g. asking students to make their own plan for the assignment).

These two different mechanisms support the formation of different forms of scaffolds that either structure or problematize aspects of the learning assignment. Structuring scaffolds give context suitable examples of metacognitive activities to the group (e.g., showing students an example plan for their mind mapping task when they start the task: "What would you like to learn; let's make a mind map with important topics to learn about, for instance the climate"). Structuring scaffolds encourage students to pay attention to the information in the scaffold, but do not invite them to construct their own metacognitive activities. On the other hand, problematizing scaffolds pose context suitable questions that elicit students' metacognitive activities (e.g., asking students to plan their mind mapping task when they start the task: "How are you going to make the mind map?"). Previous studies showed that problematizing scaffolds, such as question prompts, elicit students' explanations and support articulation of students' thinking (Chi et al. 2001; Davis and Linn 2000; King 1998, 2002). Thus, problematizing scaffolds are likely to encourage students' constructive activities.

Different scaffolds could influence the intra-group interaction differently. Scaffolds that drive intra-group interaction could stimulate metacognitive activities beyond the direct impact of the scaffolding. Interaction among the group members can further stimulate metacognitive activities when students start to elaborate, discuss and reflect on each other's contributions. Referring back to the example of the structuring scaffold for planning, students can elaborate on this example, adjusting and shaping the group's plan for the mind map task. In response to the problematizing scaffold, on the other hand, students can articulate their own metacognitive ideas, have discussions about (conflicting) views, exchange and share, leading to co-constructed metacognitive activities.

From different studies into collaborative learning, we know that different instructional designs, such as scripting, jigsaw designs and role play, can successfully support interaction among students (Dillenbourg 1999; Rummel and Spada 2005; Strijbos and De Laat 2010; Weinberger and Fischer 2006). For example, scripts provide procedural guidelines to support discussion and have been shown to increase the interaction among students (Weinberger and Fischer 2006). Previous research also indicates that scaffolding stimulates interaction in small groups (Chi et al. 2001; Davis and Linn 2000; King 1998, 2002). Specifically, structuring scaffolds seem to support sharing of ideas by students (King 1998, 2002), whereas problematizing scaffolds tend to elicit articulation of student's thinking, consequently driving co-construction among group members (Chi et al. 2001; Davis and Linn 2000). As such the different forms of scaffolds may lead to different interactions among the group members. Problematizing scaffolds, in the form of questions, are likely to support the articulation of group members' existing metacognitive knowledge, followed by a collaborative co-construction of new metacognitive activities to be applied to the task at hand. Alternatively, structuring scaffolds, providing examples, are expected to elicit a discussion of the example (shared metacognitive activities) neither leading to articulation of students own knowledge nor supporting collaborative co-construction of new metacognitive activities. Even though there are studies that show that scaffolds facilitate interaction, few studies have systematically compared the effect of different forms of scaffolds on students' interaction in small groups.

To summarize, the main difference between scaffolding in individual and group setting is that scaffolding can positively influence the interaction among the group members. Different forms of scaffolds may affect the interaction of the group members differently, leading to either shared or co-constructed social metacognitive activities among group members. By examining the impact of different scaffolds on the intra-group social metacognitive interaction and hence student's learning, this study tries to make a significant contribution to existing knowledge base on the role of scaffolds in fostering intra-group social metacognitive interaction and the related impact on students' metacognitive knowledge.

This study

The purpose of this study is to examine the effect of different metacognitive scaffolds on intra-group social metacognitive interaction. In addition, we also examine how intra-group social metacognitive interactions are related to students' individual metacognitive knowledge. To our knowledge, there are few empirical studies available on the effects of scaffolding on intra-group social metacognitive interaction. We report an experiment in which elementary school students collaboratively worked on a research task in a computer-based environment with three metacognitive scaffolding conditions (none, structuring, and problematizing). The main questions addressed in this study are:

1. What are the effects of metacognitive scaffolds on intra-group social metacognitive interaction?
2. How is a student's participation in intra-group social metacognitive interaction related to the student's metacognitive knowledge?

Based on findings from earlier research that show that scaffolds increased interaction among the group members (Chi et al. 2001; Davis and Linn 2000; King 1998, 2002), we expect to find more shared and co-constructed metacognitive activities in the discourse of groups receiving scaffolds compared to the groups receiving no scaffolds (Hypothesis 1).

Research on college students has shown that structuring scaffolds increase interaction but only problematizing scaffolds increases the articulation of students' thought processes that leads to co-construction of new knowledge (Chi et al. 2001; Davis and Linn 2000). When group members articulate their metacognitive ideas (think-aloud), this can create opportunities for students to become more engaged in each other's thinking and actively co-construct knowledge collectively (Iiskala et al. 2011). Therefore, we expect to find more co-constructed metacognitive activities in the discourse of groups receiving problematizing scaffolds compared to groups receiving structuring scaffolds (Hypothesis 2).

Findings from collaborative learning have shown that high quality interaction, such as sharing and co-constructing knowledge, is beneficial for learning (Roschelle 1996; Teasley 1997; Weinberger et al. 2007). Therefore, we expect that a student's participation in different types of high quality intra-group social metacognitive interaction, such as shared and co-constructed social metacognitive activities, is positively related to a student's metacognitive knowledge (Hypothesis 3).

Methods

Participants

We used 18 triads (54 students, 23 boys and 31 girls; Grade 4 (9), Grade 5 (27) and Grade 6 (18) from 6 classes in 3 elementary schools), consisting of 6 control triads (18 students), 6 structuring scaffolds triads (18 students) and 6 problematizing scaffolds triads (18 students). The teachers assigned students to heterogeneous triads (52) using the following procedure. First, we asked teachers to rate the students as low, middle or high achievers based on their reading, writing and computing performance. Then, the teachers created triads containing one low, one middle and one high achiever. Every triad had to include students of both genders. Next, we randomly assigned the triads to the three experimental conditions, equally divided across the classes.

Virtual learning environment and assignment

The e-learning environment used in this study is called Ontdeknet (Discovery net in English), see screenshots in Appendix 2. It focuses on supporting students in their virtual collaboration with experts, real people who have an expertise about the topic the students are studying (Molenaar 2003). The experts provide students with information about their expertise, in this case knowledge about their country through diaries they write in the e-learning environment. The contributions of the experts were edited by the editor of Ontdeknet. The teacher gave an assignment and monitored the students' progress. Collaborative learning was implemented at two levels: students collaborating with an expert in a virtual environment and with each other face-to-face in their triad with a computer. The study consisted of 8 sessions, each lasting 1 h. In the first session, the students completed a pre-test, and then received instructions about the assignment and the virtual environment. In the last session, the students completed several post-tests. All students received the same instructions, and all triads spent the same time working on the assignment (6 sessions of 1 h). During the 6 assignment sessions, the triads worked on an assignment called "Would you like to live abroad?" The goal of the assignment was to explore a country of choice (New Zealand or Iceland), write a paper on their findings and decide if they would like to live in this country. The triads worked on one computer and had access to an expert, namely an inhabitant of the country. They could consult the expert by asking questions and requesting information on different topics about the country. In a separate expert window in the computer environment, the expert provided the requested information, and questions were answered in a forum. Four sub-tasks preceded the task to write a paper about the country: (a) introducing the group to the expert, (b) writing a goal statement, (c) selecting a country and (d) specifying topics of interest on a mind map. All tasks were integrated into the working space of the triads, where they also wrote the paper. The papers of the triads were stored in the learning environment. All lessons were supervised by the same researcher.

The scaffolding system and the conditions

The computerized scaffolds were dynamically integrated into the learning environment. An attention management system (Atgentschool) was used to determine when and which scaffold to send to the learners (Molenaar and Roda 2011; Molenaar et al. 2013). This system monitored students' attention focus and, based on this information, supplied the scaffolds. The system's technical design consisted of three levels: the input level, the reasoning level and the intervention level. The input level collected information about students' attention from the students' environment. The attentional information was derived from keyboard strokes, mouse movements and event information about the groups' activities in the e-learning environment. The reasoning level selected the scaffold that was sent to the group. Different software agents assessed students' attention information to select the appropriate scaffold. The system used the following logic: a "logical" attention focus was based on the learning assignment at hand and created a list of all possible scaffolds that could support the learner at that point in time. The learner's current attention focus was compared to the logical attention focus based on the learning assignment. When current and logical attention focus matched, a scaffold was selected to support the learner with their current activity. For example, when a student was meant to fill in the mind map and was at the screen providing him the opportunity to enter the words in the mind map then, if the system detected that the student was idle, it would support the student by suggesting that he started to plan the mind map assignment. In case of a discrepancy between the current and the logical attention focus, the system was triggered to select a scaffold that could overcome the discrepancy. For example, if the student had an assignment to fill in the mind map and the system established that he was not on the correct screen, then a focus discrepancy was diagnosed and a scaffold selected to direct the attention of the learner to the mind map assignment. The system would, however, wait to provide the scaffold until it registered that the student was idle.

The intervention level determined how the scaffold was communicated to the learner. A three-dimensional virtual agent powered by Living Actor technology for the delivery of scaffolds is, in some studies, referred to as a Pedagogical Agent (Baylor 1999). The scaffolds were shown in text balloons and could be heard as spoken messages through the computer's audio output. The messages were pre-recorded by a human actor. The messages were accompanied by the agent's animations (e.g. movements of the agent's hands) and emotions (e.g. smile on the face of the agent). The students could select one of four icons to communicate with the agent, a question mark to indicate a need for help and three emotional icons indicating a happy, neutral or sad state. This user information was used as additional input. First, in all conditions, the agent mirrored the emotions of the user and, in the experimental conditions, when users indicated they were sad, scaffolds were generated faster than when users indicated they were happy.

The triads in the scaffolding conditions groups received scaffolds supporting their metacognitive activities during the first two lessons. The scaffolds were dynamically timed in the learning process by the "reasoning level" described above and the triads in both conditions received the scaffolds at the same point in the learning process. The scaffolds were delivered at times when metacognitive activities would usually be occurring in the learning process, based on Zimmerman (2002) model for self-regulated learning augmented with metacognitive theory (Veenman et al. 2005, 2006). The scaffolding system determined the appropriate moment to send a scaffold based on students' attention focus. The different types of scaffolds were triggered by the system in relation to the following changes in the attention focus of the students. Orientation activities should be performed just before selecting a task. Thus, at sub-assignment selection triads received a scaffold to orientate on the sub-assignment. Planning should be done just before starting a task. Therefore planning scaffolds were sent just before execution of the sub-assignment. Finally, monitoring should be performed during and after execution of the task. Upon saving the sub-assignment triads were shown a scaffold prompting them to monitor (Molenaar et al. 2013). For each sub-assignment three types of scaffolds were implemented: orientation, planning and monitoring scaffolds. Students in the scaffolding conditions received a minimum of 12 scaffolds.

The triads in the structuring condition (experimental group 1) received scaffolds in the structuring form, which consisted of direct support to the groups' social metacognitive activities. The triads in the problematizing condition (experimental group 2) received scaffolds in the problematizing form which were designed to elicit individual student's metacognitive activities. The triads in the problematizing condition were obliged to answer the agent's questions in an answer box on the screen, (see Fig. 2 for an example of both forms of scaffold). Table 1 shows the messages shown in the orientation, planning and monitoring scaffolds in structuring and in problematizing form for the introduction assignment. Finally, the triads in the control group did see the virtual agent, but did not receive any form of metacognitive support from the agent. The agent was included in the interface to prevent a Hawthorne effect (Franke and Kaul 1978).

Measurements

Conversation analysis

The conversations of 18 triads (108 h) were recorded with voice recorders, transcribed and analyzed in five steps. Because we were interested in the interaction between students, the unit

Fig. 2 An example of a structuring (*left*) and a problematizing (*right*) scaffold

of analysis was the conversation turn of each speaker (n=51,339 turns). Each conversation turn was coded with one main category code, (see Table 2 for an overview) and one subcategory code (see Appendix 1). All main categories were mutually exclusive and exhaustive categories, as were all subcategories within a main category.

Several categories (cognitive activities, metacognitive activities, off task activities, not codable activities and teacher activities) were derived from the coding scheme of Veldhuis-Diermanse (2002). Additionally, two types of activities were added; relational activities specific to the group setting and procedural activities specific to the learning environment. The cognitive activity category contained turns concerning the content of the task and elaboration of this content (e.g., reading the material, asking a question about the domain, discussing the learning task, elaborating specific issues and summarizing previous contributions of group members, see Appendix 1 Table 8). Metacognitive activity included turns that monitor or control cognitive activities, based on Meijer et al. (2006) subcategories: orientation, planning, monitoring, evaluation and reflection (see Appendix 1 Table 9). Relational activity included turns regarding social interaction between the students, such as engaging other group members, discussing the division of labor among the group members, and supporting other group members (see Appendix 1 Table 10). Procedural regulation entailed turns in which students discussed where to click and how to use the learning environment. Off task refers to activities that were not related to either the learning task at hand or the task domain, and teacher activities were contributions made by the teacher.

To determine inter-coder reliability, two raters independently coded two randomly selected protocols (2,500 turns). There was excellent agreement for the main categories (Fleiss 1981): Cohen's kappa K=0.92. The kappa was highest for the metacognitive activities, K=0.94, and lowest for the non-codable category, K=0.82.

Table 1 Example of structuring and problematizing scaffolds for the introduction assignment

Situation	Structuring scaffold	Problematizing scaffold
Orientation on introduction	Before we start, I would like to know who you are, please introduce yourselves.	Why are you going to introduce yourselves?
Planning of Introduction	I am going to show you an example of how to introduce yourselves: I am David, I am 12 years old and like to play games on the internet.	How are you going to introduce yourselves?
Monitoring of introduction	Thank you, I will send your introduction to the expert.	Did you introduce yourselves as planned?

Table 2 Main categories of coding scheme

Main category	Description
Metacognitive activity	Turns about monitoring and controlling the cognitive activities during learning
Cognitive activity	Turns about the content of the task and the elaboration of this content
Relational activity	Turns regarding the social interaction between the students in the triad
Procedural activity	Turns regarding the procedures to use the learning environment
Teacher/researcher	Turns made by the teacher or the researcher.
Off task	Turns not relevant to the task.
Not codable	Turns too short or unclear to interpret

Second, in order to analyze the intra-group social metacognitive interaction we needed to determine metacognitive episodes. Metacognitive episodes are sequences of turns that are connected and consist of at least one metacognitive turn. We determined episodes based on turns that shared the same focus of regulation of learning. The episode started with the first metacognitive activity and ended after the last turn dealing with the same focus of regulation of learning. An example of a metacognitive episode: “We start with the first chapter of our paper; What are we going to discuss in the first chapter?; Lets read the information about animals in New Zealand”. Here the episodes starts with a metacognitive remark detailing the plan students have. Students continue to discuss the plan and how to realize it. After these turns the students continue to read the information about New Zealand, which ends this episode focusing on the discussion of the next line of action. Two researchers independently determined the metacognitive episodes of the 18 triads; the intercoder-agreement was 71 %. All inconsistencies between the two coders were re-coded in mutual agreement.

Third, we determined the form of metacognitive episodes based on whether the episode contains individual, other or social metacognitive activities. Following Iiskala et al. (2011) and Hadwin & Oshige (2011), we distinguished the form of metacognitive activities based on the level the contributions were focused on, i.e. individual using “I”, other using “you” or social using “we”. Individual metacognitive activities occur when a student is regulating his or her own cognitive activities; for example “Stop! I need to think about this”. Other-metacognitive activities occur when a group member regulates the individual activity of another group member, for example “What are you doing?”; “I am trying to understand this question”. Social metacognitive activities occur when one or more group members regulates their collaborative cognitive activities, for example: “What are we writing?”; “The goal statement”; “What is the goal statement?”; That is where you write what you want to learn”. Cohen’s kappa was 0.91 which indicates excellent agreement (Fleiss 1981).

Fourth, we coded the type of intra-group social metacognitive interaction per episode. As described above, we distinguish four types of intra-group social metacognitive interaction, ignored, accepted, shared and co-constructed social metacognitive activities. Ignored social metacognitive activities occur when the group members do not relate to or engage with another group member’s metacognitive activity, for example: “Lets read this chapter”; and another group member responds “I am so happy”, which indicates that he had ignored the previous metacognitive remark. Accepted social metacognitive activities occur when the group members reply to a metacognitive activity with a cognitive activity, for example: “Lets write down hobbies”; a group member answers” My hobbies are Tennis and Ballet”. Shared social metacognitive activities occur when group members exchange metacognitive activities, for example: “I do not know what to do next”; “True, but I do not know what to do either”; “What do you think?" We see that these students share their ideas, but do not build on each other's comments. Finally, when group members do build on each other's metacognitive activities, we speak of co-constructed social metacognitive activities, for example: "Let's start again with the first part of the chapter"; "Ok what are we describing in the first chapter"; "We discuss the language of the country, let's read the chapter about language". Here the students really build on each other's comments and make a new plan to work on. The Cohen's kappa for this category was 0.86, indicating good agreement among the coders (Fleiss 1981).

Students' metacognitive knowledge was measured by asking them to imagine they were going to do the same assignment again. They were asked to write down in which steps they would proceed on this assignment as such making their knowledge about their strategic behavior (person & strategy) and the current task explicit. The answers were scored against a full procedural overview made by the researchers. The full procedural overview consisted of 18 steps; examples of steps were "plan the learning task", "activate prior knowledge" and "monitor the activity of the group". The maximum score was 18 points. 10 % of the tests were scored by two independent researchers (kappa =0.83).

Analysis

As mentioned earlier, the purpose of our study is to determine the effect of metacognitive scaffolding and different forms of scaffolds on the intra-group social metacognitive interaction and to examine the relation between different types intra-group social metacognitive interaction and students' metacognitive knowledge.

For the first research question the analyses were done at the group level. To test the first hypothesis, we assessed the types of intra-group social metacognitive interaction of the triads. The dataset contained 108 h of recordings and 51 339 separate speech episodes (turns), with 3,702 metacognitive episodes of which 3,519 were classified as social metacognitive activities.

Due to the fact that the variable co-constructed social metacognitive activities was not normally distributed, we used non-parametric statistics to test our hypothesis (Field 2012). The Mann–Whitney test was selected to test the first and second hypotheses. First, the effect of scaffolding was assessed, comparing the scaffolding group to the control group; after which the effect of different forms of scaffolds was tested comparing the problematizing and structuring group.

As we previously found that triads receiving scaffolding performed more metacognitive activities then triads in the control group (Molenaar et al. 2010), we decided to use relative frequencies of the different types of intra-group social metacognitive interaction. Thus the mean reported indicates the relative frequency, for example the mean for ignored metacognitive activities in the control group was 0.22, which indicates that 22 % of all social metacognitive episodes in the control group were ignored metacognitive activities. The effect sizes were calculated using the effect size estimate r (Rosenthal 1991) defining 0.1 as a small effect, 0.3 as a medium effect and 0.5 as a large effect.[1]

For the second research question, data from individual students was analyzed without taking into account the conditions. The aim was to determine if there was a relation between students' participation in different types of interaction (especially high quality interaction, shared and co-constructed social metacognitive activities) and a student's metacognitive knowledge (hypothesis 3). Stepwise regression analyses were performed using the absolute

[1] We use the effect size r for both the parametric and non-parametric test following Rosenthal (1991) as described in (Field 2005). The r for non-parametric data is calculated on the basis of the data from the Mann–Whitney test, namely $r = \frac{z}{\sqrt{N}}$

number of different types of interaction related to social metacognitive activities by a student as a predictor of that student's metacognitive knowledge.

Results

Influence of scaffolding on the type of intra-group social metacognitive interaction

Table 3 shows the relative frequency of 4 types of intra-group social metacognitive interaction for the control and scaffolding conditions. Triads in the experimental group (m=0.09) performed significantly more co-constructed metacognitive activities than the control group (m= 0.05), (U (16)=15.5, p=0.03 (one sided; r=0.45). On the other types of intra-group social metacognitive interaction no significant differences between the control and the experimental conditions were found. Triads in the experimental group (m=0.20) performed somewhat less ignored metacognitive activities than triads in the control condition (m=0.22), (U (16)==26, p=0.19 (one sided), r=0.23). The experimental group (m=0.29) had somewhat less accepted metacognitive activities than the control group (m=0.32), (U (16)==20.5, p=0.08 (one sided), r=0.34). Finally, the experimental group had somewhat more shared metacognitive episodes (m=0.42) than the control group (m=0.41) (U (16)==26, p=0.19 (one sided), r=0.22).

Table 4 shows the relative frequencies of the 4 types of intra-group social metacognitive interaction in the two experimental conditions. Triads in the problematizing condition (m= 0.18) had significantly less ignored metacognitive activities than those in the structuring condition (m=0.22) (U (10)==6, p=0.03 (one tailed), r=0.56) and significantly more co-constructed metacognitive activities (problematizing m=0.13 vs structuring m=0.05), (U (10)=5, p=0.02 (one tailed), r=0.60). On the other types of intra-group social metacognitive interaction no significant differences between the two experimental conditions were found. Triads in the problematizing condition (m=0.29) had the same quantity of accepted metacognitive activities as triads in the structuring condition (m=0.29), (U (10)=18, p=0.53 (one tailed), r=0.01) and the triads in the problematizing condition (m=0.40) had less shared metacognitive activities than the triads in the structuring condition (m=0.44) (U (10)=12, p= 0.19 (one tailed), r=0.28).

In order to illustrate how problematizing scaffolds stimulated co-constructed social metacognitive activities, a typical example of how a group responded to problematizing scaffolds is shown in Table 5.

The avatar is asking students to make a plan for filling in the mind map that they need to make about the topic they are researching, in this case New Zealand. At the start of the example, Kim's response to the scaffold is a quite simple suggestion ("Simply by putting in words about the country"). Max comments on this suggestion by trying to clarify Kim's

Table 3 Relative frequency of 4 types of intra-group social metacognitive interaction in the scaffolding and the control conditions

	Ignored metacognitive activities m (sd)	Accepted metacognitive activities m (sd)	Shared metacognitive activities m (sd)	Co-constructed metacognitive activities m (sd)
Control condition	0.22 (0.04)	0.32 (0.06)	0.41 (0.08)	0.05 (0.03)
Experimental group (scaffolding)	0.20 (0.04)	0.29 (0.05)	0.42 (0.05)	0.09 (0.06)

Table 4 Relative frequency of 4 types of interaction of intra-group social metacognitive interaction in the structuring and the problematizing conditions

	Ignored metacognitive activities m (sd)	Accepted metacognitive activities m (sd)	Shared metacognitive activities m (sd)	Co-constructed metacognitive activities m (sd)
Structuring condition	0.22 (0.03)	0.29 (0.05)	0.44 (0.05)	0.05 (0.03)
Problematizing condition	0.18 (0.04)	0.28 (0.06)	0.40 (0.05)	0.13 (0.07)

comment ("Putting in words? But how do we select the words?"). Tom commences to answer this question ("What we have to") which is then finished by Kim ("What we would like to learn about the country"). Max combines the two previous suggestions ("We have to put in words about topics that we would like to learn more about") and Kim continues to clarify this by providing an example ("For instance, about the climate or the language spoken"). Then Tom adds to this plan by indicating that they need to concentrate on the 6 most important aspects ("Right, and then we have to select the 6 most important topics"). After this Max closes the discussion by concluding that this is the plan and that they should commence ("Ok, let's get started. What do you want to learn about?"), which is put into action by Kim ("Well I like to know if….").

Through discussing the way to make the mind map, the group members plan the task and construct a better understanding of it. In this episode, we see that each student's metacognitive activity triggers another group member's metacognitive activity. Furthermore, each metacognitive activity provides validating feedback to the previous one and provides material

Table 5 An example of co-constructed social metacognitive activities initiated by a problematizing scaffold

Student name	Code	Turn
Avatar	Problematizing scaffold	How are you going to make the mind map about New Zealand?
Kim	Metacognitive activity: planning	Simply by writing down words about the country
Max	Metacognitive activity: planning	Putting in words? But how do we select the words?
Tom	Metacognitive activity: planning	What we have to …
Kim	Metacognitive activity: planning	What we would like to learn about the country
Max	Metacognitive activity: planning	We have to put in words about topics that we would like to learn more about
Kim	Metacognitive activity: planning	For instance, about the climate or the language spoken
Tom	Metacognitive activity: monitoring	Right, and then we have to select the 6 most important topics
Max	Metacognitive activity: planning	Ok, let's get started. What do you want to learn about?
Kim	Cognitive activity: processing	Well I would like to know if ….

from which to co-construct the next one, thereby validating the importance of metacognitive activities and encouraging its subsequent use and development.

We also see groups that received problematizing scaffolds during the first two lessons continue to engage in co-constructed metacognitive activities after the scaffolding has ceased. In Table 6, we see how students built on each other's contributions in a co-constructed social metacognitive activity without a scaffold initiating the interaction. At the start of the example, Susan and Jacob are processing information and writing a chapter of their assignment in the e-learning environment. The metacognitive episode starts with Rob who monitors the group's progress ("This is what we had to write down. The summary of the first diary of the expert."). Jacob answers, indicating they have already done more ("This was already more than the first summary"). Rob persists in his observation ("This is about the country. Are we still writing about the country?"). Susan supports Jacob's assertion ("No, actually we are not writing about the country, but about distances"). Rob then changes his opinion, agrees with the others and suggests a change of strategy ("Then we have to do it differently"). Jacob continues his line of thinking and proposes a new plan of action ("Then we can make two chapters. The country and the distances"). Susan agrees with this plan putting it into practice ("Ok, hold on. I will make a new chapter") and so does Rob, adding the new chapter's name ("Let's begin the chapter about the distances"). This is the end of the social metacognitive episode because Susan continues at the cognitive level by writing ("Yes, we can use the sentence 'trains drive for long days'"). Again in this example, we see how group members built upon each other's contributions resulting in a truly reciprocal interaction.

Table 6 An example of co-constructed social metacognitive activities without a scaffold starting the interaction

Student name	Code	turn
Susan	Cognitive activity: processing	Trains drive a long way,
Jacob	Cognitive activity: processing	Doctors often come by airplane, komma, they…...
Susan	Cognitive activity: processing	With the airplane….
Rob	Metacognitive activity: monitoring	This is what we had to write down. The summary of the first diary of the expert.
Jacob	Metacognitive activity: monitoring	This was already more than the first summary
Rob	Metacognitive activity: evaluation	This is about the country. Are we still writing about the country?
Susan	Metacognitive activity: evaluation	No, actually we are not writing about the country, but about distances
Rob	Metacognitive activity: monitoring	Then we have to do it differently;
Jacob	Metacognitive activity: planning	Then we can make two chapter. The country and the distances
Susan	Metacognitive activity: planning	Ok, hold on. I will make a new chapter
Rob	Metacognitive activity: planning	Let's begin the chapter about the distances
Susan	Cognitive activity: processing	Yes, we can use the sentence 'trains drive for a long way….

Table 7 An example of shared social metacognitive activities

Student name	Code	turn
Jim	Cognitive activity: Processing	There are many fruits in New Zealand
Jan	Cognitive activity: processing	And the kiwi is an animal
Loes	Metacognitive activity: Monitoring	What did you just write?
Jim	Metacognitive activity: monitoring	What a bad idea!
Loes	Metacognitive activity: Monitoring	Now it is completely wrong
Jan	Cognitive activity: processing	And the kiwi is an fruit
Jim	Cognitive activity: processing	There are many apples too

Relation between a students' participation in of intra-group social metacognitive interaction and a student's metacognitive knowledge

The second research question deals with the relation between student's engagement in different types of intra-group social metacognitive interaction and their metacognitive knowledge. As mentioned earlier, we expect that intra-group social metacognitive interaction increases student's metacognitive knowledge, especially interactions in which students discuss social metacognitive activities, such as shared and co-constructed social metacognitive activities.

To test this, we conducted stepwise regression (method: enter) with the number of ignored, accepted, shared and co-constructed social metacognitive activities as predictors of a student's metacognitive knowledge. Only shared social metacognitive activities significantly predicted student's metacognitive knowledge $B=0.27$, $t(45)=2.41$, $p=0.02$. Student's engagement in shared metacognitive activities explains 12 % of the variance in their metacognitive knowledge. The other social metacognitive activities did not predict student's metacognitive knowledge significantly.

In Table 7, we illustrate how the groups' shared metacognitive activities can increase students' metacognitive knowledge. The students are writing about fruit in New Zealand. Jan adds a sentence that is not in line with the goal of the chapter ("And the kiwi is an animal"). Loes immediately notices the irregularity in their writing and comments on it ("What did you just write?). Jim agrees with Loes and repeats her comment in a different way ("What a bad idea!"). Finally, Loes adds ("Now it is completely wrong") and Jan changes the sentence to ("And the kiwi is a fruit") and Jim continues with ("There are many apples too"). Here we see the group members exchanging metacognitive remarks without adding anything to each other's comments. The sharing of these comments can impact students' metacognitive knowledge as this monitoring act of Loes is made very explicit for the group members by Jim's repetition. This allows the group members to understand when to use monitoring activities during the learning process in an appropriate matter and also to value this act in relation to the chapter they are writing.

Discussion and conclusion

This study investigated the effects of scaffolding on the groups' intra-group social metacognitive interaction and examined the relation between the students' participation in different types of interaction and students' metacognitive knowledge. We analyzed the conversations of 18 triads, consisting of 54 students, in three conditions. We found that scaffolding increases high quality intra-group social metacognitive interaction. Moreover problematizing scaffolds induce less ignored and more co-constructive social metacognitive activities than structuring scaffolds. Finally, students' metacognitive knowledge was predicted by shared social metacognitive activities.

Scaffolding facilitated intra-group social metacognitive interaction. Groups receiving scaffolds engaged in significantly more co-constructed social metacognitive activities, confirming our first hypothesis. However, contrary to expectations, we did not find a significant increase of shared social metacognitive activities, although the trend was in the expected direction. These results indicate that scaffolding does alter the interaction among the group members, leading to more advanced discussions of social metacognitive activities.

With respect to the effect of different forms of scaffolds on intra-group social metacognitive interaction (second hypothesis), triads in the problematizing condition showed more co-constructed social metacognitive activities than triads in the structuring condition. Moreover, groups in the problematizing condition ignored each other's metacognitive activities fewer times than groups receiving structuring scaffolds. These findings confirm our second hypothesis. As expected, problematizing scaffolds led to the articulation of students' metacognitive ideas and this triggers new social metacognitive contributions in which each new contribution provides validating feedback to the previous one. Thus, problematizing scaffolds first elicit individual group members' metacognitive ideas which, in turn, sparks the co-construction of social metacognitive activities. Moreover, groups tend to continue to co-construct social metacognitive activities even when the scaffolding ceases.

Furthermore, there was a reduction of ignored social metacognitive activities. This suggests that groups in the problematizing condition are more attuned to other group members' attempts to regulate the group's learning and therefore are more engaged in these type of social metacognitive activities. This finding agrees with previous studies (Barron 2000, 2003) in which the difference between successful and unsuccessful groups in science learning was investigated. The successful groups were not showing more problem solving attempts than unsuccessful groups. The difference was the number of attempts that were actually discussed in the group. In our study, similarly, all groups showed attempts to regulate their learning. Yet, groups receiving problematizing scaffolds seemed to be more successful because they were less likely to ignore attempts to regulate the learning and more likely to get involved in co-constructing social metacognitive activities.

Finally, students' metacognitive knowledge is significantly related to their participation in intra-group social metacognitive interaction (third hypothesis). This agrees with findings from collaborative learning research showing that high quality interaction fosters learning (Teasley 1997; Roschelle 1996; Stahl et al. 2006; Suthers et al. 2010). Surprisingly, co-constructed social metacognitive activities did not predict metacognitive knowledge. A possible explanation for this is that co-constructed social metacognitive activities occur relatively rarely, even in the scaffolding conditions. There were only 12 instances of co-constructed social metacognitive activities during structuring scaffolds, which accounts for only 5 % of all social metacognitive episodes. In comparison, there were 27 instances during problematizing scaffolds, which comprised 13 % of all social metacognitive episodes.

In general, only about half of the group's social metacognitive activities are discussed among the group members. This suggests that there is space for improving intra-group social metacognitive interaction. There are two possible benefits improving of intra-group social metacognitive interaction. First, improved interaction may support alignment between group members' task perception, goals and strategies. In an individual setting, we know that this alignment supports learning outcomes and a similar mechanism may act in group settings. Second, as shown in this study, students' shared social metacognitive interaction contributes to their individual metacognitive knowledge. Thus metacognitive scaffolding in a social setting goes further than merely triggering socially regulated learning. It also has the potential to act as a training tool for enhancing the development of a student's own and fellow group member's metacognitive knowledge.

Based on the findings of this study, it could be proposed that, as with other instructional design methods such as scripting, jigsaw designs and role play (Dillenbourg 1999; Rummel and Spada 2005; Strijbos and De Laat 2010; Weinberger and Fischer 2006), metacognitive scaffolding could function as an instructional design method to support intra-group social metacognitive interaction during collaborative learning. As hypothesized, scaffolding in a collaborative setting can stimulate social metacognitive activities beyond the direct impact of the scaffold when designed to generate interaction. This idea could lead to a new line of research investigating the design of scaffolds.

Therefore, we encourage further research into the design of metacognitive scaffoldings that optimize intra-group social metacognitive interaction. The fact that students' participation in intra-group social metacognitive interaction contributes to students' metacognitive knowledge, opens up a line of research dealing with metacognitive scaffolding as an instructional design method to develop students' metacognitive knowledge through interaction with their peers. This relation between scaffolding of metacognitive activities, collaboration and students' development of metacognitive knowledge is a promising avenue for new research. It could be a promising combination to enhance student's metacognitive knowledge and skills for future learning in complex computer-based environments.

Appendixes

Appendix 1 Coding Schema

Table 8 Subcategories of cognitive activities

Cognition	Description	Example
Reading out	Reading out loud the information from the instruction, the learning environment or statements of the avatar.	You are going to write a paper. My name is Jan I live in Iceland……
Processing	Cognitive processing of the task through: Selection of pictures Writing of text Naming mind map words	I find this picture goes with the texts In New Zealand there are many different animals…..
Questioning	Asking a question that is related to the content of the task	Do Maoris live in New Zealand?
Elaboration	Elaboration of task content: relating to other concepts, giving examples or connecting to own experiences.	If there are mountains, it is probably quite high No, you also find tobacco in cigarettes
Summarizing	Summarizing what has been said before	We have windmills, tulips, traditional clothing and cheese

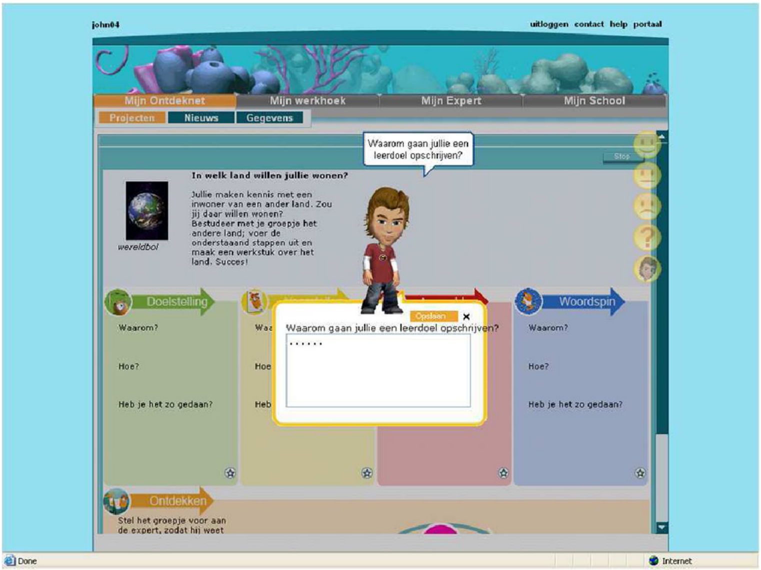
Table 9 Subcategories of metacognitive activities

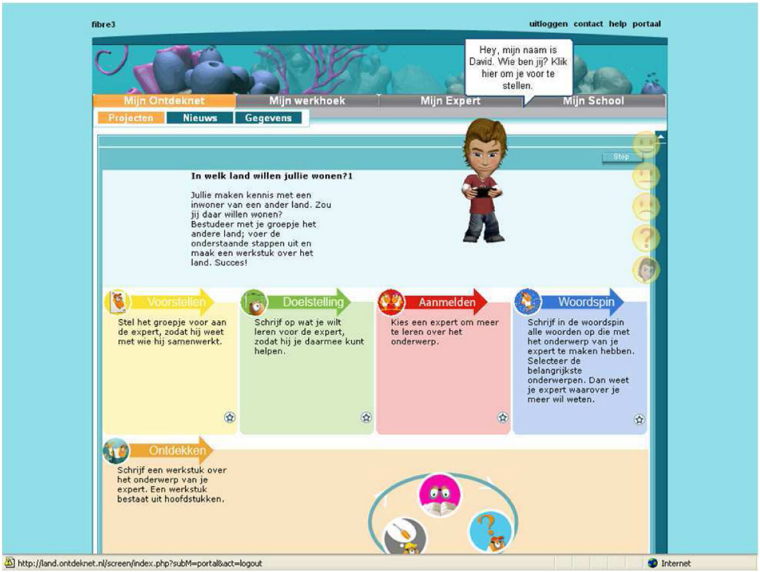
Subcategory	Description	Examples
Orientation	Orientation on prior knowledge, task demands and feelings about the task	What do we need to do? Do you know what a learning goal is?
Planning	Planning of the learning process, for instance, sequencing of activities or choice of strategies	Now we are going to ask questions.
Monitoring	Monitoring of the learning process: checking progress and comprehension of the task.	I do not understand You are doing it wrong Wait, please. Just leave it like that
Evaluation	Evaluation of the learning process; checking of the content of the learning activities.	We posted a good question These are the most important issues
Reflection	Reflection on the learning process and strategies through elaboration on the learning process.	Let me think, this is more difficult than I thought. Why do we have the most difficult task?

Table 10 Subcategories of relational activities

Relational activities	Description	Examples
Engaging	Asking group members to engage in the task	Daniek, please continue Jocye, that is not funny.
Task division	Division of tasks between the group members	She is thinking, I am asking questions and you write Pascall is typing
Support	Repetition or support of a previous speaker	We have to write a paper Yes, we have to write it
Reject	Rejection of previous speaker	No Do not do that!

Appendix 2 screenshots





References

Azevedo, R., & Cromley, J. G. (2004). Does training on self-regulated learning facilitate students' learning with hypermedia? *Journal of Educational Psychology, 96*(3), 523–535.

Azevedo, R., Moos, D. C., Greene, J. A., Winters, F. I., & Cromley, J. G. (2008). Why is externally-facilitated regulated learning more effective than self-regulated learning with hypermedia? *Educational Technology Research and Development, 56*(1), 45–72.

Barron, B. (2000). Achieving coordination in Collaborative Problem-Solving Groups. *The Journal of the Learning Sciences, 94*(4), 403–436.

Barron, B. (2003). When smart groups fail. *The Journal of the Learning Sciences, 12*(3), 307–359.

Baylor, A. (1999). Intelligent agents as cognitive tools for education. *Educational Technology, 39*(2), 36–40.

Chi, M. (2009). Active-constructive-interactive: a conceptual framework for differentiating learning activities. *Topics in Cognitive Science, 1*(1), 73–105.

Chi, M. T. H., Siler, S., Jeong, H., & Hausmann, R. (2001). Learning from human tutoring. *Cognitive Science, 25*, 471–534.

Damon, W. (1984). Peer education: the untapped potential. *Journal of Applied Developmental Psychology, 5*, 331–343.

Davis, E. A., & Linn, M. (2000). Scaffolding students' knowlegde integration; Prompts for reflection in KIE. *International Journal of Science Education, 22*(8), 819–837.

Dillenbourg, P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed.), *Collaborative-learning: cognitive and computational approaches* (pp. 1–19). Oxford: Elsevier.

Doise, W. (1990). The development of individual competencies through social interaction. In H. C. Foot, M. J. Morgan, & R. H. Shute (Eds.), *Children helping children* (pp. 43–64). New York: Wiley.

Doise, W., & Mugny, G. (1984). *The social development of the intellect*. Oxford: Pergamon press.

Field, A. (2005). *Discovering statistics with SPSS*. London: Sage.

Field, A. (2012). *Discovering statistics with SPSS*. London: Sage.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: a new area of cognitive-developmental inquiry. *American Psychologist, 34*(10), 906–911.

Fleiss, J. (1981). *Statistical itletlzods for rates and proportions*. New York: John Wiley and Sons.

Franke, R. H., & Kaul, J. D. (1978). The Hawthorne experiments: first statistical interpretation. *American sociological review*, 623–643.

Goos, M., Galbraith, P., & Renshaw, P. (2002). Socially mediated metacognition: creating collaborative zones of proximal development in small group problem solving. *Educational Studies in Mathematics, 49*, 193–223.

Hadwin, A., & Oshige, M. (2011). Self-regulation, co-regulation, and socially shared regulation: Exploring perspectives of social in self-regulated learning theory. *Teachers College Record, 113*(6)

Hadwin, A.F., Järvelä, S., & Miller, M. (2011). Self-regulated, co-regulated, and socially-shared regulation of learning. In B. J. Zimmerman & D. H. Schunk (Eds.), *Handbook of self-regulation of learning and performance* (pp. 65–84). New York, NY: Routledge.

Hatano, G. (1993). Time to merge Vygotskian and constructivist conceptions of knowledge acquisition. In E. A. Forman, N. Minick, & C. A. Stone (Eds.), *Contexts for learning: Sociocultural dynamics in children's development* (pp. 153–166). New York: Oxford University Press.

Hmelo-Silver, C. E., & Azevedo, R. (2006). Understanding complex systems: some core challenges. *The Journal of the Learning Sciences, 15*(1), 53–61.

Iiskala, T., Vauras, M., Lehtinen, E., & Salonen, P. (2011). Socially Shared metacognition within primary school pupil dyads' collaborative processes. *Learning and Instruction, 21*, 379–393.

Järvelä, S., & Hadwin, A. (2013). New frontiers: regulating learning in CSCL. *Educational Psychologist, 48*(1), 25–39.

King, A. (1998). Transactive peer tutoring: distributing cognition and metacognition. *Educational Psychology Review, 10*(1), 57–74.

King, A. (2002). Promoting thinking through peer learning. *Theory Into Practice, 41*(1), 33–39.

Lin, X., & Sullivan, F. R. (2008). Computer context for supporting metacognitive learning. In J. Voogt & G. Knezek (Eds.), *International handbook of information technology in primary and secondary education* (Vol. 1, pp. 281–298). New York: Springer.

Liskala, T., Vauras, M., & Lehtinen, E. (2004). Socially-shared metacognition in peer learning? *Hellenic Journal of Psychology, 1*(2), 147–178.

Meijer, J., Veenman, M. V., & van Hout-Wolters, B. H. (2006). metacognitive activities in text-studying and problem-solving: development of a taxonomy. *Educational Research and Evaluation, 12*(3), 209–237.

Mercer, N. (1996). The quality of talk in children's collaborative activity in the classroom. *Learning and Instruction, 6*, 359–377.

Molenaar, I. (2003). Exploration-net: Online collaboration. In D. Lassner & C. McNaught (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2003* (pp. 398–400). Chesapeake, VA: AACE.

Molenaar, I., & Järvelä, S. (2014). Sequential and temporal characteristics of self and social regulated learning. *Metacognition and Learning*. doi:10.1007/s11409-014-9114-2.

Molenaar, I., & Roda, C. (2008). Attention management for dynamic and adaptive scaffolding. *Pragmatics Cognition, 16*(2), 224–271.

Molenaar, I., & Roda, C. (2011). Attention management for dynamic and adaptive scaffolding. In I. E. Droir (Ed.), *Technology Enhanced Learning and Cognition* (pp. 51–96). Amsterdam/Philadelphia: John Benjamins Publishing Company.

Molenaar, I., Chiu, M. M., Sleegers, P. J. C., & van Boxtel, C. A. M. (2011). Scaffolding of small groups' metacognitive activities with an avatar. *International Journal of Computer Supported Collaborative Learning, 6*(4), 601–624.

Molenaar, I., van Boxtel, C. A. M., & Sleegers, P. J. C. (2010). The effects of scaffolding metacognitive activities in small groups. *Computers in Human Behavior, 26*(6), 1727–1738.

Molenaar, I., van Boxtel, C. A. M. & Sleegers, P. J. C. (2013). Dynamic metacognitive scaffolding in small groups. In R. Azevedo & V. Aleven (Eds.), *International Handbook of Metacognition and Learning Technologies* (pp. 561–574). New York: Springer Science.

Molenaar, I., van Boxtel, C.A. M., & Sleegers, P. J.C. (2014). Metacognitive scaffolding during collaborative learning: A promising combination. *Metacogntion and learning*.

Nelson, T. O. (1996). Consciousness and metacognition. *American Psychologist, 51*, 102–116.

Pea, R. D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education and human activity. *The Journal of the Learning Sciences, 13*(3), 423–451.

Piaget, J. (1932). *The language and thought of the child* (2nd ed.). London: Routledge and Kegan Paul.

Puntambekar, S., & Hubscher, R. (2005). Tools for scaffolding students in a complex learning environment: what have we gained and what have we missed? *Educational Psychologist, 40*(1), 1–12.

Rafal, C. (1996). From co-construction to takeovers: science talk in a group of four girls. *Journal of Learning Sciences, 5*, 279–293.

Reiser, B. J. (2004). Scaffolding complex learning: the mechanisms of structuring and problematizing student work. *The Journal of the Learning Sciences, 13*(3), 273–304.

Roschelle, J. (1996). Learning by collaborating: Convergent conceptual change. In T. Koschmann (Ed.), *CSCL: Theory and practice of an emerging paradigm* (pp. 209–248). Mahwah: Erlbaum.

Rosenthal, R. (1991). *Meta-analytic procedures for social research (revised)*. Newbury Park: Sage.

Rummel, N., & Spada, H. (2005). Learning to collaborate: an instructional approach to promoting collaborative problem solving in computer-mediated settings. *The Journal of the Learning Sciences, 14*(2), 201–241.

Salomon, G. (1993). *Distributed cognitions; psychological and educational considerations*. Cambridge: Cambridge University Press.

Schoor, C., & Bannert, M. (2012). Exploring regulatory processes during a computer-supported collaborative learning task using process mining. *Computers in Human Behavior, 28*(4), 1321–1331.

Sharma, P., & Hannafin, M. J. (2007). Scaffolding in technology-enhanced learning environments. *Interactive Learning Environments, 15*(1), 27–46.

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 409–426). Cambridge: Cambridge University Press.

Strijbos, J., & De Laat, M. (2010). Developing the role concept for computer-supported collaborative learning: an explorative synthesis. *Computers in Human Behavior, 26*(4), 495–505.

Suthers, D., Dwyer, N., Medina, R., & Vatrapu, R. (2010). A framework for conceptualizing, representing and analyzing distributed interaction. *International Journal of Computer Supported Collaborative Learning, 5*, 5–42.

Teasley, S. (1997). Talking about reasoning: How important is the peer in peer collaboration? In L. B. Resnick, R. Saljo, C. Pontecorvo, & B. Burge (Eds.), *Discourse, tools and reasoning: Essays on situated cognition* (pp. 361–384). Berlin: Springer.

Van Boxtel, C. (2004). Studying peer interaction from three perspectives: the example of collaborative concept learning. In J. L. v d Linden & P. Renshaw (Eds.), *Dialogic learning: shifting perspectives to learning, instruction and teaching* (pp. 125–144). Dordrecht: Kluwer Academic Publishers.

Van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher–student interaction: a decade of research. *Educational Psychology Review, 22*(3), 271–296.

Veenman, M. V. J., Kok, R., & Blote, A. W. (2005). The relation between intellectual and metacognitive skills in early adolescence. *Instructional Science, 33*(3), 193–211.

Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: conceptual and methodological considerations. *Metacognition Learning, 1*(1), 3–14.

Veldhuis-Diermanse, A. E. (2002). *CSCL-Learning? Participation, learning activities and knowledge construction in computer-supported collaborative learning in higher education*. University of Wageningen

Volet, S., Vauras, M., & Salonen, P. (2009). Self- and social regulation in learning contexts: an integrative perspective. *Educational Psychologist, 44*(4), 215–226.

Webb, M. (2009). The teacher's role in promoting collaborative dialogue in the classroom. *British Journal of Educational Psychology, 79*, 1–28.

Weinberger, A., & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Computers & Education, 46*, 71–95.

Weinberger, A., Stegmann, K., & Fischer, F. (2007). Knowledge convergence in collaborative learning: concepts and assessment. *Learning and Instruction, 17*(4), 416–426.

Winne, P. H., & Hadwin, A. F. (2010). Self-regulated learning and socio-cognitive theory. In B. McGaw, E. Baker, & P. Peterson (Eds.), *International encyclopedia of education* (3rd Edition). New York.

Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*, 89–100.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: an overview. *Theory Into Practice, 42*(2), 64–70.